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Fish Assemblages at a Deep-Water Sewage Disposal Site (DWD-106)

by

J. A. Musick, J. C. Desfosse and E. D. Grogan

A Final Contract Report Submitted by the
Virginia Institute of Marine Science,
The College of William and Mary

to

The National Marine Fisheries Service

November 30, 1992

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Introduction

Deep-water dumpsite 106 is located over the continental slope and rise about 106 miles east of New Jersey (Fig. 1). From March 1986 to July 1992 approximately eight million wet metric tons of sewage sludge were disposed there per year (Robertson and Redford, 1992). Because of the potential impact of this dumping on deep-sea ecosystems, NOAA/NMFS contracted the Virginia Institute of Marine Science, College of William and Mary (VIMS) to make otter-trawl collections in and around DWD 106 in 1990 and 1991. Specific objectives of these collections were:

1. To sample the demersal megafauna, especially fishes;
2. To provide frozen series of dominant species of fishes and invertebrates to NMFS for subsequent heavy metal and organic analyses;
3. To provide a description of the demersal fish community structure in the area;
4. To compare these data with similar data collected from 1973 to 1978 from DWD 106 and an adjacent area to the south near Norfolk submarine canyon.

This final contract report summarizes the results of these studies.

Methods and Materials

Current data collection

All trawl collections were made with a 13.7 m (headrope) four-seam semi-balloon otter trawl, with 4.45 cm stretch mesh in wings and body, 1.27 cm stretch mesh liner in the codend, steel China "V" otter doors, four 25.4 cm diameter glass floats on the headrope, and with 22.9 m bridles fished from a single trawl warp. Tow speed was maintained at 1.8 to 2.2 knots and durations were 0.5 hr at depths <1000 m, 1 hr $\geq$1000 m, and longer $\geq$2000 m (Musick, 1979; Sulak, 1982). For analyses all tows were standardized to 1 hr and catch per area (m^2) was calculated based on a mean vessel speed of 2 knots and net sweep area of 6.7 m (a value determined with net sondes in our previous work) (Middleton, 1993). Thus, a 60 min tow sampled an area of 24.83 x 10^3 m^2. All current research was done from the R/V Delaware II. A summary of station locations of the two cruises (DE II 90-09, and DE II 91-09) was given by Wilk and McMillan (1992) (Figs. 1 and 2, Tables 1 and 2).

After capture all fishes were identified, counted, measured, and weighed by species. Invertebrates were sorted and weighed by major taxonomic groups (i.e., echinoids, holothurians, crustaceans, etc.) with the exception of red crab, *Geryon quinquedens*, and american lobster, *Homarus americanus*, which were weighed separately. After initial identification selected series of dominant fish species and invertebrates were provided to NMFS personnel for further processing and freezing for subsequent chemical analyses ashore (Wilk and McMillan, 1992).

Historical Data Set

From 1973 to 1978 trawling was conducted on the continental slope and rise (using the methods outlined above) from Hudson Submarine Canyon (ca. 39° 00 N) to south of Norfolk Submarine Canyon (36° 30' S). A total of 177 successful stations were occupied (Figs. 3 and 4). Cruises were conducted on the R/V Columbus Iselin (cruises 73-10, 78-02), R/V. James M. Gillis (cruises 74-04, 75-08, 76-01), R/V Delaware II (cruise 74-02) and the R/V Advance II (cruise 78-01). Station data for the cruises are summarized in Musick (1979), Musick, et. al., (1975), Musick and Sulak (1979), Sulak (1982) and Middleton and Musick (1986).

Data Analyses

Abundance, Biomass and Species Richness

In both the present and historical data sets numerical abundance for each station was expressed as catch-per-unit-effort:

$$\log_{10}\left(\frac{X}{1000m^2}+1\right)$$

(where X = total number of specimens) and plotted against depth. Biomass was treated similarly.

Although many different measures of species richness are available (Magurran, 1988) we chose to use Margalef's "D" index (Margalef, 1951):

$$D=\frac{(S-1)}{\ln N}$$

where N is the total number of individuals and S the total number of species at each station. We have used this index in our previous work (Musick, et. al., 1975; Musick, 1979; Musick and Sulak, 1979) and have retained it in the present analysis for ease of comparison. Noting the wide range of variation inherent in trawl catch data, particularly from deepwater where actual fishing time on the bottom is difficult to determine, we chose to compare bathymetric trends in abundance, biomass and species richness graphically in the recent and historical data sets for our initial analysis, rather than applying more rigorous but potentially misleading statistical methods (Yaccoz, 1991). In addition, we compared the mean biomass of fishes from DWD-106 with that of other stations from similar depths in the recent data set. Means were tested using the "t" test (Zar, 1974).

<u>Community Structure</u>

The historical data have been analyzed using numerical classification to define faunal changes with depth in several of our previous reports (Musick, 1979; Musick and Sulak, 1979; Sulak, 1982). Although differing in minor detail, all previous analyses have shown rapid faunal changes on the continental slope (200-2000 m) as reflected by many station groups in the cluster analysis, and very slow faunal change (few station groups) on the continental rise and abyssal plain (>2000 m). In the present study, we again subjected the historical data set to numerical classification and used the Canberra-Metric dissimilarity measure (Lance and Williams, 1966; 1967) because it is sensitive to uncommon as well as abundant species (Boesch, 1973; Clifford and Stephenson, 1975). We chose the flexible clustering strategy (B = -0.25) (Boesch, 1973; 1977) because it tends to group entities together more readily than the other commonly used strategies such as "group average" or "unweighted pair group" (Sokal and Sneath, 1963). As in the other analyses above, species catches were standardized to a 60 min. tow time, but were then transformed using the square-root transformation before clustering. This transformation helps to reduce the effects of contagion and occasional large catches typical in trawl sampling (Taylor, 1953), and is appropriate with abundances similar to those encountered in our trawl catches (tens to hundreds) (Clifford and Stephenson, 1975). In the past (Musick, 1979) we have also used the log transformation before cluster analysis, and in practice can see little difference in the performance of the two transformations. Very rare species (those present at <3 stations) were culled from the analysis because they provide little information and in most cases serve only to introduce noise into the classification (Boesch, 1977).

After cluster analysis of the historical data, dominant species were identified within principal station groups. A species was defined as dominant if it occurred among the five most abundant species in at least 20% of all stations in that group.

We considered cluster analysis to be redundant with the recent (1990-91) smaller data set, and chose instead to define bathymetric station groups based on the historical analysis above and those cited previously. Station Group 1 included 2 outer shelf stations (90, 107 m), Station Group 2 included 5 middle slope stations (379-642 m), Station Group 3 included 6 lower slope stations (1226-1700 m), and Station Group 4 included 23 continental rise stations (2070-2952 m). Dominant species were identified within these station groups for comparison with the historical data set.

Results and Discussion

Recent Trawl Data

The numbers and total weights of all demersal fish species collected on cruise DE II 90-09 are presented by station in Appendix 1. Likewise, demersal species from cruise DE II 91-09 are presented in Appendix 2. In 1990, 68 demersal species comprising 1193 individuals weighing 257.6 kg were captured at 17 successful trawl stations. In 1991, 66 demersal species comprising 1858 individuals weighing 412.1 kg were captured at 19 successful trawl stations. Pelagic species from DE II 90-09 and

DE II 91-09 are presented in Appendices 3 and 4, respectively. Because it is impossible to determine where in the water column pelagic species have been captured, they have been removed from all following analyses.

In 1990, 817 subsamples comprised of 14 demersal fish species, holothurians, and echinoids were processed for chemical analyses ashore (Table 3). Likewise, in 1991, 598 finfish subsamples comprised of 11 demersal fish species and numerous bulk subsamples of Cancer borealis, Geryon quinquedens, pandalid shrimps, echinoids and asteriods were processed for chemical analyses ashore (Table 4). Preliminary results of these analyses have been presented by Thurberg et al. (1992).

Community Structure

Cluster analysis of the historical data set yielded six primary groups (Fig. 5): Group 1, an outer shelf group (69-239 m) comprised in turn of summer (1A) and winter (1B) components; Group 2, a shelf-slope transition group (108-390 m); Group 3, a mid-slope group (403-1109 m); Group 4, a lower slope group (1142-1908 m); Group 5, a continental rise group (1916-2933 m); and Group 6, an abyssal plain group (2745-4829 m).

Although earlier studies of bathymetric faunal change concluded that there was strong faual zonation from the edge of the continental shelf down to the abyss (Menzies et al., 1973; Haedrich et al., 1975; Haedrich et al, 1980). Musick (1976, 1979) suggested that demersal fish communities were distributed within a gradually changing coenocline (Whittaker, 1975) from the shelf edge down into the abyss with mosaics of species overlapping in distribution and relative abundance. Musick (1986) noted further that the relative gradient of this coenocline reflected the rate of faunal change and was steepest where environmental gradients were steepest on the continental slope between 180 m and 2000 m. In this region the topographic gradient is steeper than on the shelf or rise. The benthic substrates are more heterogeneous. The bottom temperature drops from 12C to 3C, and the relative pressure changes around five-fold (Musick, 1986). Carney et al. (1983) and Haedrich and Merrett (1990) have also recognized that bathymetric faunal change is gradual rather than rigidly zoned.

Species Richness

The bathymetric pattern of species richness for the historical and recent data sets are shown in Figs. 6 and 7, respectively. The species richness pattern for the recent data set was similar to that of the historical set with a maximum on the lower slope ($\cong$ 2000 m) and then a decrease down into the abyss. The recent values from the outer shelf and upper slope were not as high as some of the historical values, probably because of the smaller number of recent samples from there.

Species richness and related measures of species diversity in the deep sea have received much attention in the literature (see Grassle, 1989; and Gage and Tyler, 1991 for recent exhaustive reviews). Musick (1976 and 1979) noted that species richness of demersal fishes began to decrease at shallower depths, closer to the continental margin than any other major taxocoene. He attributed this to the high relative position most fishes occupy on the trophic pyramid, the exponential decrease of available energy with depth and distance from the continental margin (Rowe, 1983), and ecological entropy. Thus, as energy becomes limiting, increased competition, competitive exclusion, and reduced species richness occurs in the highest trophic levels first. Musick (1988) further showed that selachiens which are the apex predators in most bathyal communities decline in diversity and abundance at even shallower depths than the teleosts that occupy trophic positions beneath them. Likewise, Rex (1976 and 1983) noted a decrease in diversity of predatory gastropods at shallower depths than for gastropod deposit feeders. Unfortunately, other workers who have defined bathymetric patterns of species richness in other benthic taxa have paid little attention to the role of trophic position. Rex (1983) correctly noted that the effects of energy availability, trophic position, predation (as disturbance), and competition in fishes, gastropods, and other taxa he examined could best be explained by the dynamic equilibrum model suggested by Huston (1979). Species diversity in this model results from a dynamic interaction among rates of competitive displacement, the frequency of population reduction caused by predation or other perturbations, and intrinsic population growth rates.

Species Dominance

Dominant species are listed by station group in Tables 5 and 6 and for the recent and historical data set, respectively. More species are included in the historical set because many more stations were sampled within a given depth range, and a wider depth range was sampled. Recent Group 1 was bathymetricly comparable to historical Group 1. Urophycis regia was by far the most important species in both data sets with minor differences in other species because the recent data set was comprised only of two stations. Recent Group 2 bridged both historical groups 2 and 3 bathymetrically. (This was necessary in order to provide a sufficient number of recent samples for anlaysis). The dominants listed for recent Group 2 also occurred either in historical Group 2 or 3, but there was a greater affinity with Group 3, N. bairdi, P. chesteri, G. cynoglossus, L. verrilli, and S. kaupi all making major contributions to both data sets. Recent Group 3 was comparable in depth to historical Group 4 and both groups showed the same top five dominant species (although not exactly in the same order); S. kaupi, C. carapinus, A. agassizii, A. rostrata and D. intronigra. Recent Group 4 was bathymetrically comparable to historical Group 5, and showed the same top five species, but C. carapinus was ranked second in the recent data set and fourth in the historical set.

Abundance and Biomass

The bathymetric pattern of numerical abundance from the recent data set is presented in Figure 8. A marked decline in abundance with depth was evident. The pattern was similar to that observed in the historical data set (Fig. 9), although the abundance values at stations <1000 m in the recent data were within the lower part of the abundance range from the historical data set at similar depths probably because of the small number of recent samples at shallow depths. The wide range of variability in the historical set at shallower depths is obvious (Fig. 9). Abundance patterns in the two data sets were very similar between 2000 m and 3000 m, the depth range comprising the dumpsite and environs immediately downstream from the dumpsite.

The bathymetric pattern of biomass from the current data set (Fig. 10) was also similar to that of the historical data set, (Fig. 11) and in particular the biomass values from the dumpsite and downstream (2000-3000 m) were very similar to those from similar depths in the historical set.

Patterns of decreasing numerical abundance and biomass of fishes with depth are well known and have been demonstrated in our earlier studies (Musick, 1979; Musick and Sulak, 1979; Sulak, 1982), and by studies conducted by others in nearby areas (Haedrich, et al., 1980; Carney, et al., 1983). These studies showed that off New England and the middle-Atlantic slope, the numerical abundance decreased at a more rapid rate than the biomass of fishes. This led Polloni, et al. (1979) to define the "bigger-deeper" phenomenon wherein the size of fish was reported to increase with depth. Middleton and Musick (1985) however showed that for some species of macrourids the pattern was really "smaller-shallower" where large specimens traversed a wide depth range and smaller specimens were restricted to shallower depths. Merrett et al. (1991a) also noted a smaller-shallower pattern for bathyal fishes in the eastern Atlantic. Length frequency analysis of the historical data set by station group and depth (Fig. 12) support Middleton and Musick (1985). Smaller size modes predominated at the shallower station groups, but became increasingly less important in deeper groups (4, 5 and 6). Absolute abundance of large fish (≥400 mm SL) also decreased with depth (Fig. 12). (Percent frequency in this figure may be misleading because total sample size decreased from N=23,106 at upper slope Group 2 to N=193 in abyssal Group 6). Very large fish (≥500 mm SL) were absent in the shallowest groups (1 and 2), because of gear selectivity. Foell and Musick (1979) showed that the relatively small (13.7 m) net used does not effectively sample larger fishes such as squaloid sharks on the outer continental shelf where bottom temperatures are warmer, fish metabolic rates are much higher (Smith, 1978) and species are more active than on the lower slope and deeper. Merrett et al. (1991b) also noted that the catchability of large fish is lower in smaller trawls at shallower depths. Other studies using larger trawls on the outer continental shelf of the mid-Atlantic region (Grosslein and Azarovitz, 1982; Colvocoresses and Musick, 1985) have shown that large fishes are abundant there.

Van Dover et al. (1992) noted that organic loading from sewage disposal near DWD-106 was of the same order of magnitude as seasonal pulses of phytodetritus, thus doubling the rate of delivery of organic material to benthic ecosystems there. Furthermore, she provided evidence through analysis of carbon, nitrogen and sulphur isotope compounds that sewage derived organic matter (SDOM) at DWD-106 had become incorporated into the deep-sea food web and could be detected in two benthic surface deposit feeders, the urchin <u>Echinus</u> <u>affinus</u> and the holothurian <u>Benthodytes</u> <u>sanguinolenta</u>. However, she could find no evidence of SDOM in subsurface deposit feeders, suspension feeders, or motile predators or scavengers (including fishes). Grassle (1992) reported that two species of polychaete worms not found in earlier studies nearby were abundant near DWD-106 where the bottom sediments had been enriched with SDOM. In addition, Hecker (1992) made observations along the downstream (southwestern) edge of DWD-106 using the remotely operated vehicle, *Jason*. She reported that large, active foraging urchins, starfish and holothurians were abundant near the dumpsite, but smaller ophiuroids dominated at a similar depth at a control site to the east. These studies only point to qualitative changes in the benthic community in a limited area southwest of the dumpsite, and to incorporation of SDOM into a limited component (surface sediment feeders) of this ecosystem.

Consequently, it is not surprising that there was no discernible increase in fish biomass or abundance in the area surrounding DWD-106 in our initial analysis which compared demersal fish abundance and biomass before and during sewage sludge dumping from the entire sampling area located from Hudson Canyon to Norfolk Canyon.

We also compared the mean biomass of demersal fishes at recent stations closest to DWD-106 (where other workers have found biologically observable changes presumably associated with SDOM) to biomass at all other recent stations at similar depths. Thus, the mean biomass ($\log_{10}$ X+1) at Stations H6, 9, H12 and 15 from 1990, and H6, H7, and H12 from 1991 (n = 7) was compared to the mean of the other successful continental rise stations (2070-2952m), (n = 14). No significant difference was found ($t_{.05}$ = 2.093). Statistical comparison within years also were not significant.

The dispersal and ultimate fate of sewage sludge dumped at DWD-106 is complex and has been difficult to measure and model (Bothner and Grassle, 1992; Dragos et al., 1992). Although predominant surface currents are to the southwest of DWD-106 (Butman et al., 1992), the intermittant effects of cyclonic Gulf-Stream rings (Berger et al., 1992; Aikman, 1992), and less well-known deeper currents such as the Western Boundary Under Current (Hamilton et al., 1992) add to the complexity of attempting to define the flux of SDOM to benthic ecosystems near the dumpsite. Preliminary results of sediment trap studies (Hunt et al., 1992) found higher mass flux southwest of DWD-106 than to the northeast during the summer. Differences in winter were not as well defined and indeed mass flux at a station near Hudson Submarine Canyon, well-removed from, and upstream of the dumpsite had fluxes as high as 1 or 2 orders of magnitude higher than those found near the dumpsite. In addition, the same authors, using metals and organic compounds and C, N, and S stable isotope ratios as "natural" labels for the sewage sludge could find no evidence of contamination >60 nmi from the dumpsite. Furthermore, estimates of metabolic rates in the sediment at DWD-106 and several areas to the north and south were very similar (Sayles and Martin, 1991) which suggests that the impact of SDOM at DWD-106 may have little effect on benthic production there.

Conclusions

No detectable changes in demersal fish biomass, abundance, or species richness were found at or near DWD-106 after sewage sludge dumping. Also species dominance was similar before and after dumping. Other studies suggest that discernible biological effects of SDOM are confined to a relatively small area close to the dumpsite. Even though input of organic material may be doubled in this small area, its effects have not become apparent in the fish community because most fishes there are wide-ranging and are two or three trophic levels removed. Thus, the potential increased production signal may be masked by the relatively small area affected compared to the total active feeding ranges of the fishes involved, and entropy in the food web.

List of Tables

TABLE 1.

Station locations and catches for 106-Mile Dumpsite Megafauna Cruise, DE II 90-09, 20-31 August 1990. A dashed line (---) denotes no demersal megafauna captured due to the gear not fishing on the bottom which was indicated by either a water tow (WT) or a catch comprised of mesopelagic species (MPC). *

			Station Location								Depth	
Sta. No.	Sta. Code	Date M/D	Start Lat.	Start Long.	Finish Lat.	Finish Long.	Start Time	Duration (min.)	Wt. (kg)	No. Species	Start (m)	Finish (m)
1	1	8/21	39°40.9′	72°28.9′	39°40.4′	72°26.6′	2053	30	19.22	9	92	97
2	10	8/22	39°04.1′	72°51.2′	39°05.2′	72°50.2′	1422	30	2.46	3	104	106
3	11	8/22	38°56.8′	72°48.5′	38°58.9′	72°48.6′	1825	30	15.30	22	570	476
4	A4	8/23	38°52.0′	72°45.5′	38°54.3′	72°41.9′	0106	30	7.45	13	1294	1288
5	H4	8/23	38°44.0′	72°33.7′	38°51.3′	72°31.3′	0610	120	16.79	10	2653	2653
6	13	8/23	38°31.7′	72°24.3′	38°25.5′	72°15.0′	1332	120	1.52	6	2717	2745
7	HG	8/25	38°55.1′	72°02.2′	38°51.6′	72°13.2′	2000	120	2.75	7	2500	2500
8	HF	8/26	38°51.6′	72°17.5′	38°50.4′	72°06.4′	0027	120	-----	WT	2489	2342
9	9	8/26	38°48.8′	72°08.0′	38°37.5′	72°11.7′	0459	120	-----	MPC	2342	2461
10	H11	8/26	38°39.9′	72°55.1′	38°34.7′	73°00.7′	1411	30	-----	MPC	1545	1500
11	H11	8/26	38°33.5′	73°04.3′	38°39.9′	72°58.2′	1700	30	2.57	17	1514	1542
12	H2	8/26	38°33.0′	72°56.1′	38°39.6′	72°48.7′	2205	60	20.35	18	2048	2108
13	H12	8/27	38°21.7′	72°50.0′	38°31.4′	72°44.6′	0329	120	31.74	8	2620	2490
14	15	8/27	38°12.7′	72°35.8′	38°21.3′	72°26.7′	1028	120	4.71	5	2865	2862
15	26	8/27	38°08.8′	71°43.2′	38°01.2′	71°57.7′	2247	120	18.06	11	2853	2922
16	25	8/28	37°27.3′	72°44.4′	37°18.9′	72°49.3′	0912	120	8.93	5	2873	2911
17	20	8/28	37°51.2′	73°04.4′	37°42.1′	73°08.1′	1718	120	1.30	5	2498	2515
18	H10	8/29	37°54.2′	73°16.6′	37°43.7′	73°22.3′	0015	120	47.33	18	2090	2090
19	H13	8/29	37°52.6′	73°49.9′	37°56.4′	73°44.3′	0626	30	-----	MPC	1469	1341
20	H13	8/29	37°56.4′	73°44.3′	37°50.0′	73°51.1′	0843	30	6.04	18	1660	1489
21	18	8/29	38°10.0′	73°41.2′	38°13.2′	73°38.3′	1321	30	-----	MPC	557	483
22	9	8/29	38°49.5′	72°06.6′	39°00.8′	72°08.3′	2336	120	6.02	5	2448	2296
23	H6	8/30	39°04.8′	72°03.1′	39°12.1′	71°54.6′	0424	120	20.76	15	2128	2010
24	31	8/30	39°22.9′	71°20.8′	39°31.1′	71°10.1′	1119	120	26.37	15	2480	2470

*From Wilk and McMillan (1992)

TABLE 2.

Numbers of individual epibenthic finfish and invertebrates which were collected for heavy metal and organic analysis during 106 Mile Dumpsite Megafauna Cruise, DE II 90-09, 20-31 August 1990. *

Common Name	Collections (Metals/Organics)	Scientific Name
spotted hake	27/28	*Urophycis regia*
red hake	0/16	*Urophycis chuss*
cusk eel	14/15	*Lepophidium profundorum*
silver hake	0/13	*Merluccius bilinearis*
witch flounder	15/15	*Glyptocephalus cynoglossus*
rose fish	10/11	*Heliocolenus dactylopterus*
longfin hake	15/14	*Phycis chesteri*
cutthroat eel	56/59	*Synaphobranchus kaupi*
rattail	38/57	*Coryphanoides armatus*
rattail	15/11	*Nezumia bairdii*
blue hake	64/61	*Antimora rostrata*
sea cucumber	28/28	*Holothuroids*
sea urchin	30/30	*Echinoids*
halosaurs	17/32	*Halosauropsis macrochir*
rattail	15/58	*Coryphanoides carapinus*
cusk eel	12/13	*Dicrolene intronigra*
	356/461 = 817	

*From Wilk and McMillan (1992)

TABLE 3.

Station locations and catches for 106-Mile Dumpsite Megafauna Cruise, DE II 91-09 (II), 21-30 August 1990. A dashed line (---) denotes no demersal megafauna captured due to: (1) gear loss (GL); or (2) the gear was not fishing on the bottom which was indicated by either a water tow (WT) or a catch comprised of mesopelagic species (MPC). *

			Station Location								Depth	
Sta. No.	Sta. Code	Date M/D	Start Lat.	Start Long.	Finish Lat.	Finish Long.	Start Time	Duration (min.)	Wt. (kg)	No. Species	Start (m)	Finish (m)
1	1	8/22	39°38.1′	72°30.2′	39°35.8′	72°30.2′	0730	30	2.22	12	89	93
2	5	8/22	39°14.8′	72°16.9′	39°13.7′	72°20.9′	1207	30	73.55	22	444	436
3	6	8/22	39°08.1′	72°07.1′	39°03.8′	72°09.6′	1537	60	28.56	26	1700	1620
4	H6	8/22	39°04.6′	72°01.4′	38°55.6′	71°50.5′	1937	120	164.99	21	2175	2340
5	8	8/23	38°59.7′	71°55.7′	38°55.7′	71°52.1′	0112	120	-----	WT	2400	2400
6	8	8/23	39°00.0′	71°55.9′	39°04.8′	71°42.8′	0635	108	-----	GL	2325	2421
7	HG	8/23	38°57.5′	71°58.4′	38°43.0′	71°59.1′	1354	120	61.89	26	2550	2650
8	9	8/23	38°40.5′	72°07.8′	38°48.1′	72°12.1′	1928	83	-----	GL	2730	2700
9	A4	8/24	38°52.2′	72°35.4′	38°48.8′	72°43.0′	0123	30	-----	MPC	1685	1685
10	H4	8/24	38°43.7′	72°34.3′	38°43.2′	72°44.1′	0452	60	-----	MPC	2175	2260
11	H4	8/24	38°43.5′	72°43.1′	38°38.7′	72°31.5′	0808	90	18.46	20	2250	2415
12	H11	8/24	38°40.1′	72°55.0′	38°34.7′	73°01.0′	1410	50	9.19	30	1700	1680
13	H2	8/24	38°35.4′	72°52.2′	38°28.6′	72°59.0′	1739	60	1.94	17	2175	2250
14	H12	8/24	38°28.0′	72°42.4′	38°21.9′	72°56.0′	2229	90	50.34	22	2505	2540
15	15	8/25	38°11.5′	72°38.5′	38°22.4′	72°32.9′	0500	60	-----	MPC	2820	2820
16	26	8/25	38°14.5′	71°44.9′	38°03.9′	71°56.7′	1332	120	20.91	22	2950	2950
17	25	8/26	37°23.4′	72°48.8′	37°20.3′	72°59.7′	0349	120	43.95	19	2950	2960
18	24	8/26	37°15.3′	73°40.3′	37°13.8′	73°49.5′	1434	120	25.00	25	2325	2395
19	23	8/26	37°19.6′	73°53.3′	37°18.1′	73°52.0′	1948	60	7.48	17	1960	2257
20	20	8/27	37°44.9′	73°13.1′	37°39.5′	73°24.5′	0343	60	12.16	17	2380	2535
21	H10	8/27	37°51.4′	73°19.7′	37°43.7′	73°29.1′	0826	60	3.20	17	2154	2272
22	H13	8/27	37°52.7′	73°45.7′	37°45.5′	73°45.7′	1338	60	31.18	35	1552	1682
23	18	8/27	38°10.4′	73°39.9′	38°14.1′	73°37.2′	1824	30	76.89	19	593	634
24	11	8/28	38°55.4′	72°50.6′	38°57.4′	72°47.7′	0103	30	38.57	23	394	432
25	A1	8/28	38°56.7′	71°37.5′	38°46.1′	71°48.2′	0838	60	1.11	14	2620	2648
26	4	8/28	39°06.6′	71°46.2′	39°01.4′	71°34.2′	1429	60	39.13	26	2355	2380
27	31	8/28	39°22.7′	71°21.0′	39°13.5′	71°23.8′	2026	60	3.22	19	2448	2560
28	30	8/29	39°32.3′	71°23.8′	39°27.9′	71°09.2′	0146	120	90.47	20	2410	2475
29	29	8/29	39°51.0′	71°29.3′	39°50.8′	71°25.1′	0828	45	1026.64	25	560	591

* From Wilk and McMillan (1992)

TABLE 4.

Numbers of individual epibenthic finfish and invertebrates which were collected for heavy metal and organic analysis during 106 Mile Dumpsite Megafauna Cruise, DE II 91-09 (II), 21-30 August 1991. *

Common Name	Number Collected	Scientific Name
witch flounder	60	*Glyptocephalus cynoglossus*
rose fish	19	*Heliocolenus dactylopterus*
longfin hake	68	*Phycis chesteri*
cutthroat eel	73	*Synaphobranchus kaupi*
rattail	104	*Coryphanoides armatus*
rattail	37	*Nezumia bairdii*
blue hake	87	*Antimora rostrata*
halosaurs	22	*Halosauropsis macrochir*
rattail	104	*Coryphanoides carapinus*
offshore hake	17	*Merluccius albidus*
white hake	7	*Urophycis tenuis*
Jonah crab	10	*Cancer borealis*
red crab	Numerous	*Geryon quinguedens*
sea urchin	Numerous	*Echinoids*
starfish	15	*Astropectin*
starfish	2	*Asterias bulgaris*
starfish sp.	Numerous	assorted species
royal red shrimp	Numerous	*Pandalus sp.*

* From Wilk and McMillan (1992)

Table 5. Recent data set. Dominant species at each bathymetric station group; $\bar{X}$ = mean numerical contribution to stations in group; % = percent stations in group where species occurred.

	STATION GROUP							
	1 (90-107m) n=2		2 (379-642m) n=5		3 (1226-1700m) n=6		4 (1900-2960m) n=23	
SPECIES	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%
Urophycis regia	57.8	100						
Lepophidion profundorum	8.0	50						
Merluccius bilinearis	3.9	50						
Scyliorhinus retifer	1.7	50						
Raja garmani	1.3	50						
Urophycis chuss	6.9	50						
Paralichthys oblongus	5.2	50						
Peprilus triacanthus	7.7	50						
Helicolenus dactylopterus			2.4	40				
Merluccius albidus			0.6	20				
Dibranchus atlanticus			0.7	20				
Nezumia bairdi			29.1	100				
Phycis chesteri			21.1	100				
Glyptocephalus cynoglossus			19.8	100				
Lycenchelys verrilli			7.3	60				
Synaphobranchus kaupi			9.3	60	41.5	100		
Dicrolene intronigra					8.4	67		
Alepocephalus agassizii					5.1	50		
Aldrovandia phalacra					1.9	33		
Lycodes atlanticus					1.2	33		
Antimora rostrata					3.2	50	19.2	65
Coryphaenoides carapinus					10.4	67	24.9	87
Halosauropsis macrochir							9.9	78
Coryphaenoides armatus							28.9	70
Porogadus miles							4.0	61

Table 6. Historical data set. Dominant species at each bathymetric station group; $\bar{X}$ = mean numerical contribution to stations in group, % = percent stations in group where species occurred.

STATION GROUP

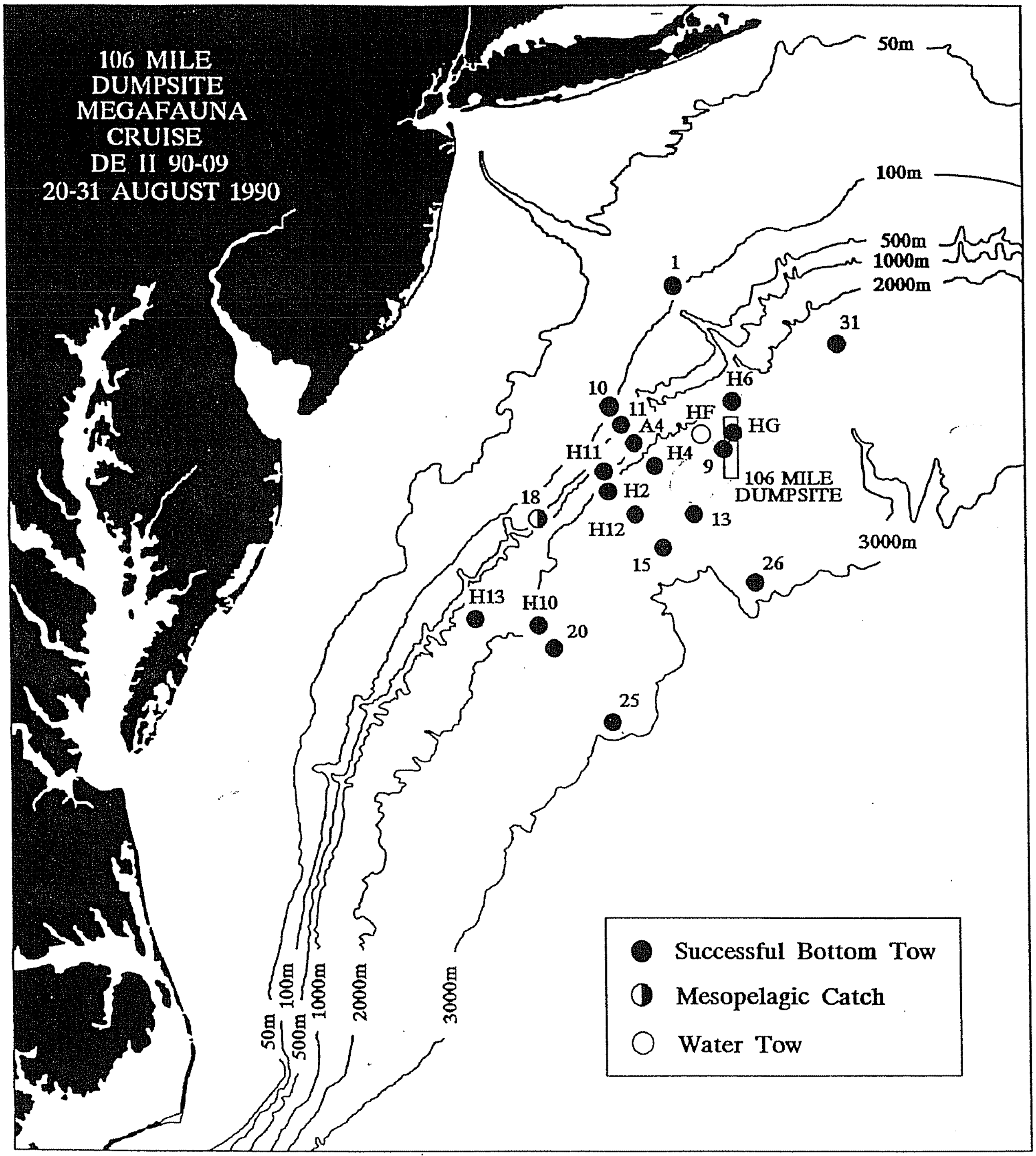
SPECIES	1a (85-199m) n=24		1b (69-239m) n=13		2 (108-390m) n=40		3 (403-1109m) n=38		4 (1142-1908m) n=30		5 (1916-2933m) n=20		6 (2745-4829m) n=12	
	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%
Prionotus carolinus			23.7	77										
Centropristis striata			11.4	92										
Stenotomus chrysops			9.8	62										
Paralichthys dentatus			4.5	69										
Urophycis regia	61.7	96	40.6	84	10.7	70								
Lophius americanus	9.3	92			3.7	85								
Citharichthys arctifrons	9.1	67	13.1	62	6.2	75								
Merluccius bilinearis	3.7	58	9.8	46	4.0	25								
Ophichthus cruentifer	2.0	67	2.4	31	1.5	78								
Lepophidion profundorum	1.6	50	4.3	31	1.4	28								
Raja garmani	1.3	63												
Paralichthys oblongus			2.6	69	0.6	33								
Peprilus triacanthus	2.0	33												
Synagrops bellus			2.4	35										
Urophycis chuss					2.4	40								
Merluccius albidus					8.6	90								
Helicolenus dactylopterus	1.0	42			21.9	93								
Enchelyopus cimbrius					2.7	53								
Myxine glutinosa					6.4	85								
Caelorinchus carminatus					5.4	78								
Chlorophthalmus agassizii					3.2	25								
Dibranchus atlanticus					1.0	30	0.9	24						
Synaphobranchus affinis							3.2	55						
Phycis chesteri					5.2	33	22.1	100						
Lycenchelys verrilli					2.1	38	10.6	84						
Glyptocephalus cynoglossus					5.2	58	11.5	100	2.6	27				
Nezumia bairdi					1.6	43	13.3	100	2.9	30				
Synaphobranchus kaupi							23.0	92	24.1	97				
Nezumia aquealis							2.4	90						
Coryphaenoides rupestris							4.8	53	0.8	27				
Lycenchelys paxilla							0.8	58						
Simenchelys parasiticus									0.5	40				
Lycodes atlanticus									1.9	73				
Aldrovandia affinis									0.7	37				
Aldrovandia phalacra									1.9	30				
Alepocephalus agassizii									5.1	97				
Dicrolene intronigra									6.1	67				
Ilyophis brunneus									2.0	67				
Polyacanthonotus rissoanus									0.6	23				
Bathytroctes microlepis									0.4	23				
Bathysaurus ferox									0.3	37				
Halargyreus johnsonii									0.3	27				
Coryphaenoides carapinus									9.5	100	6.3	80		
Antimora rostrata									26.3	100	35.3	100		
Halosauropsis macrochir									3.9	53	9.4	85		
Coryphaenoides armatus											38.7	85	76.6	100
Coryphaenoides leptolepis											0.7	30	5.5	42
Porogadus miles											1.3	40		

List of Figures

Figure 1. Location of trawl stations sampled during 106-Mile Dumpsite Megafauna Cruise, DE II 90-09, 20-31 August 1990. Solid circles indicate successful bottom tows, half filled circles mesopelagic catches, and open circles unsuccessful tows.

FIGURE 1.

Location of trawl stations sampled during 106-Mile Dumpsite Megafauna Cruise, DE II 90-09, 20-31 August 1990. Solid circles indicate successful bottom tows, half filled circles mesopelagic catches, and open circles water tows. *

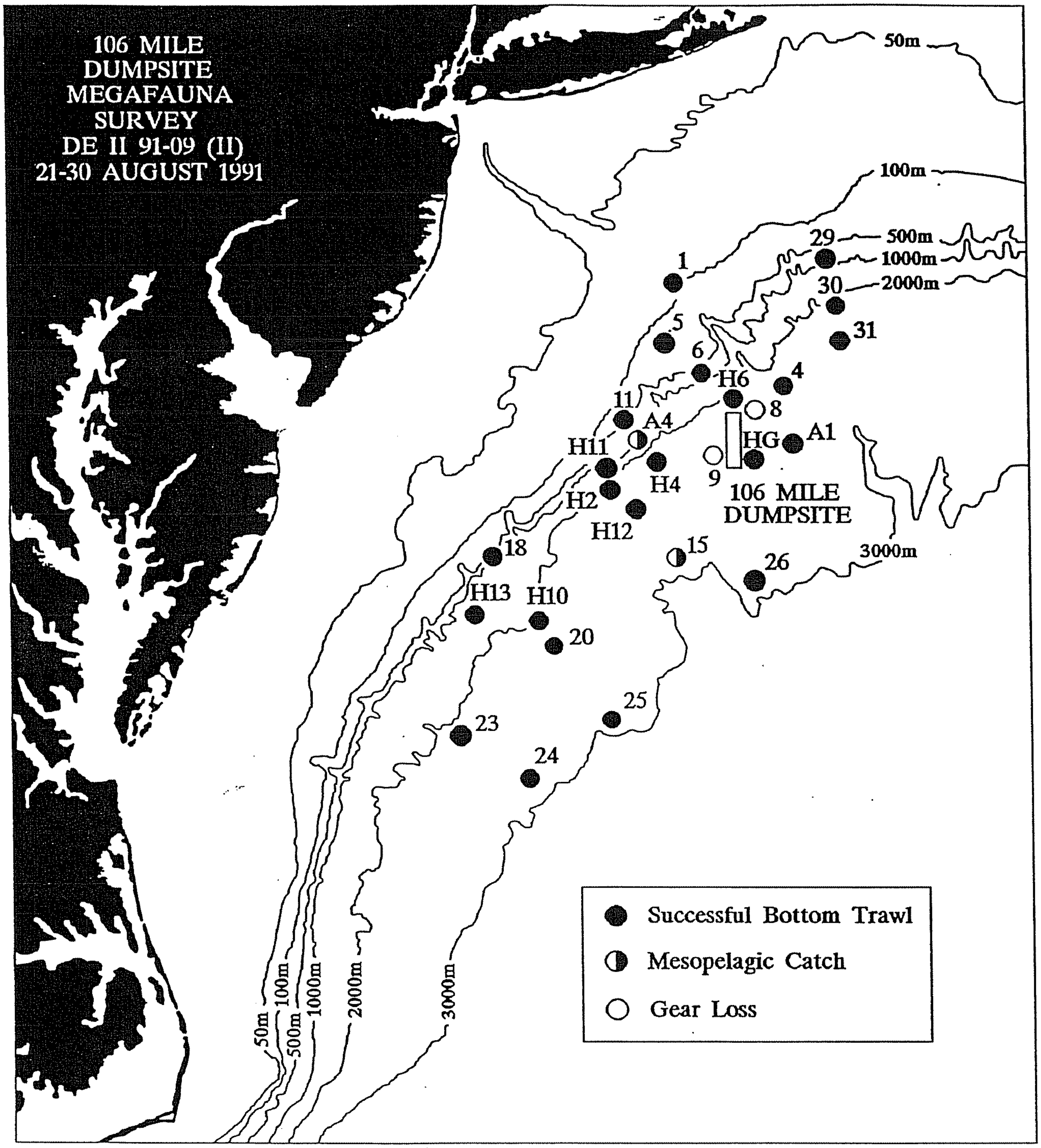


* From Wilk and McMillan (1992)

Figure 2. Location of trawl stations sampled during 106-Mile Dumpsite Megafauna Cruise, DE II 91-09 (II), 21-30 August 1991. Solid circles indicate successful bottom tows, half filled circles mesopelagic catches, and open circles unsuccessful tows.

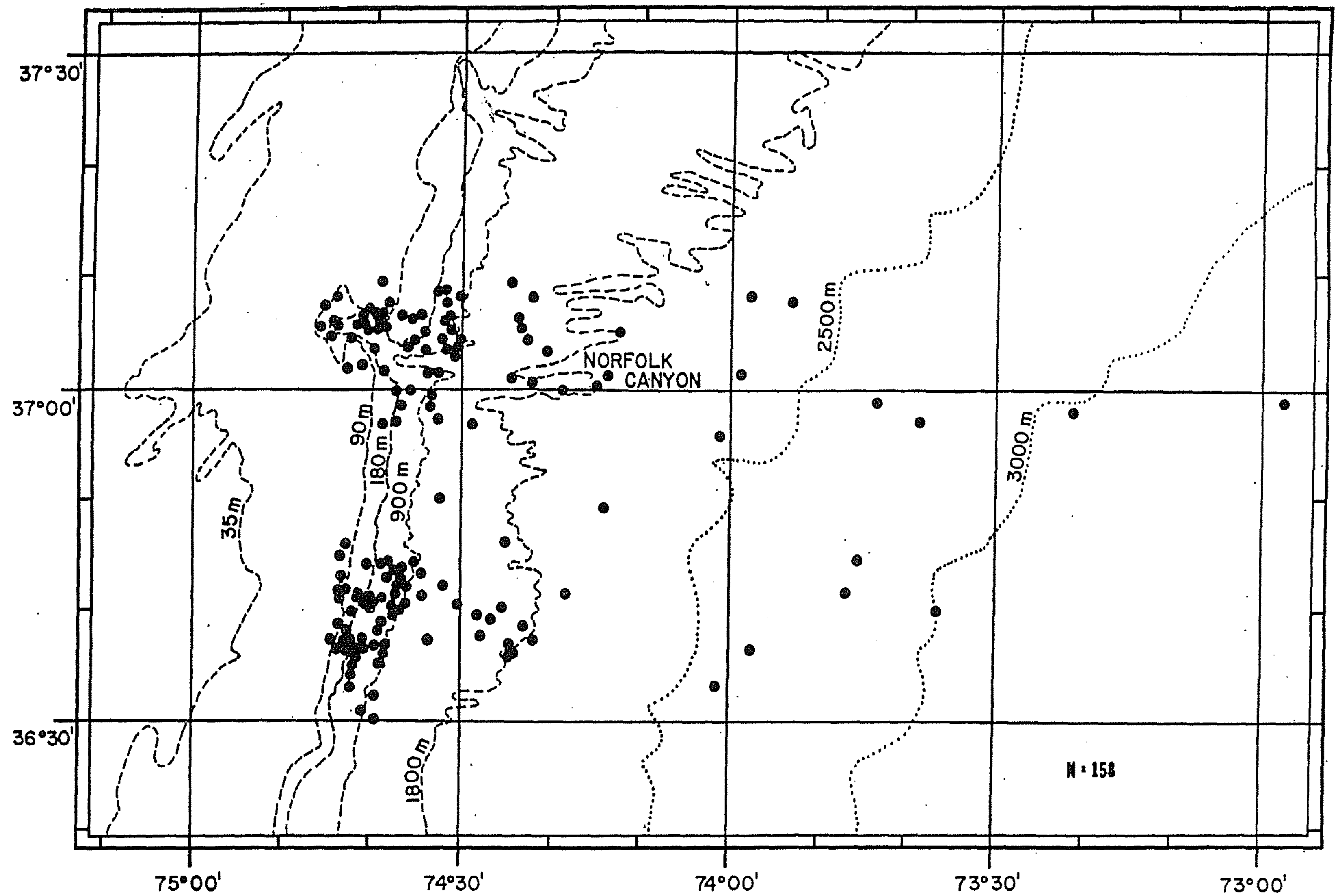
FIGURE 2.

Location of trawl stations sampled during 106-Mile Dumpsite Megafauna Cruise, DE II 91-09 (II), 21-30 August 1991. Solid circles indicate successful bottom tows, half filled circles mesopelagic catches, and open circles gear loss. *



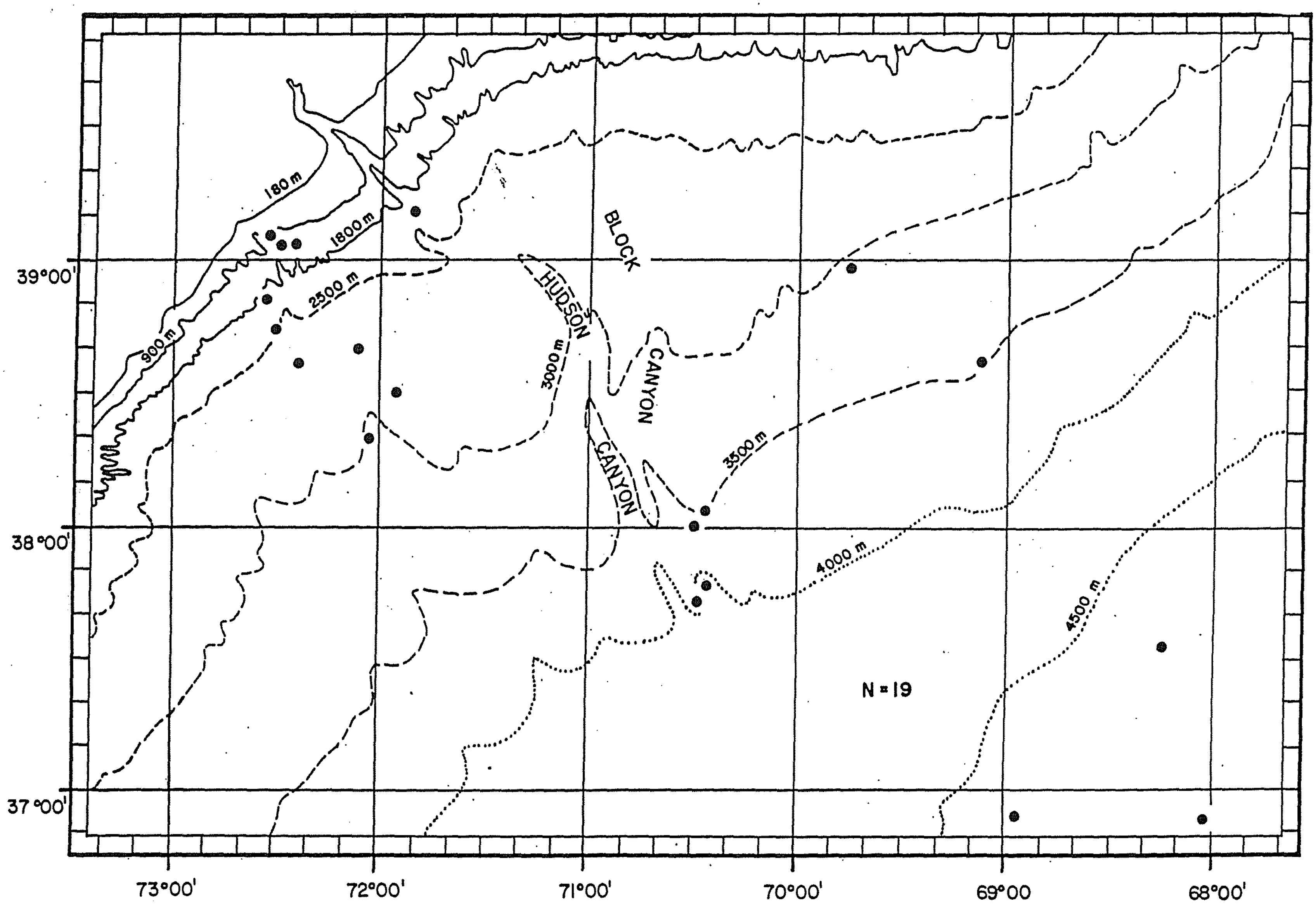
* From Wilk and McMillan (1992)

Figure 3. Station locations for historical data set cruises: _Columbus Iselin_ 73-10; and J. M. Gillis 74-04, 75-08, 76-01.



37°30'
37°00'
36°30'
75°00'
74°30'
74°00'
73°30'
73°00'
NORFOLK
CANYON
35m
90m
180m
900m
1800m
2500m
3000m
N = 158

Figure 4. Station locations for historical data set cruises: Delaware II 74-02; Advance II 78-01; and Columbus Iselin 78-02.



180 m
900 m
1800 m
2500 m
3000 m
3500 m
4000 m
4500 m
BLOCK
CANYON
HUDSON
CANYON
N = 19
39°00'
38°00'
37°00'
73°00'
72°00'
71°00'
70°00'
69°00
68°00'

Figure 5. Cluster analysis of historical data set.

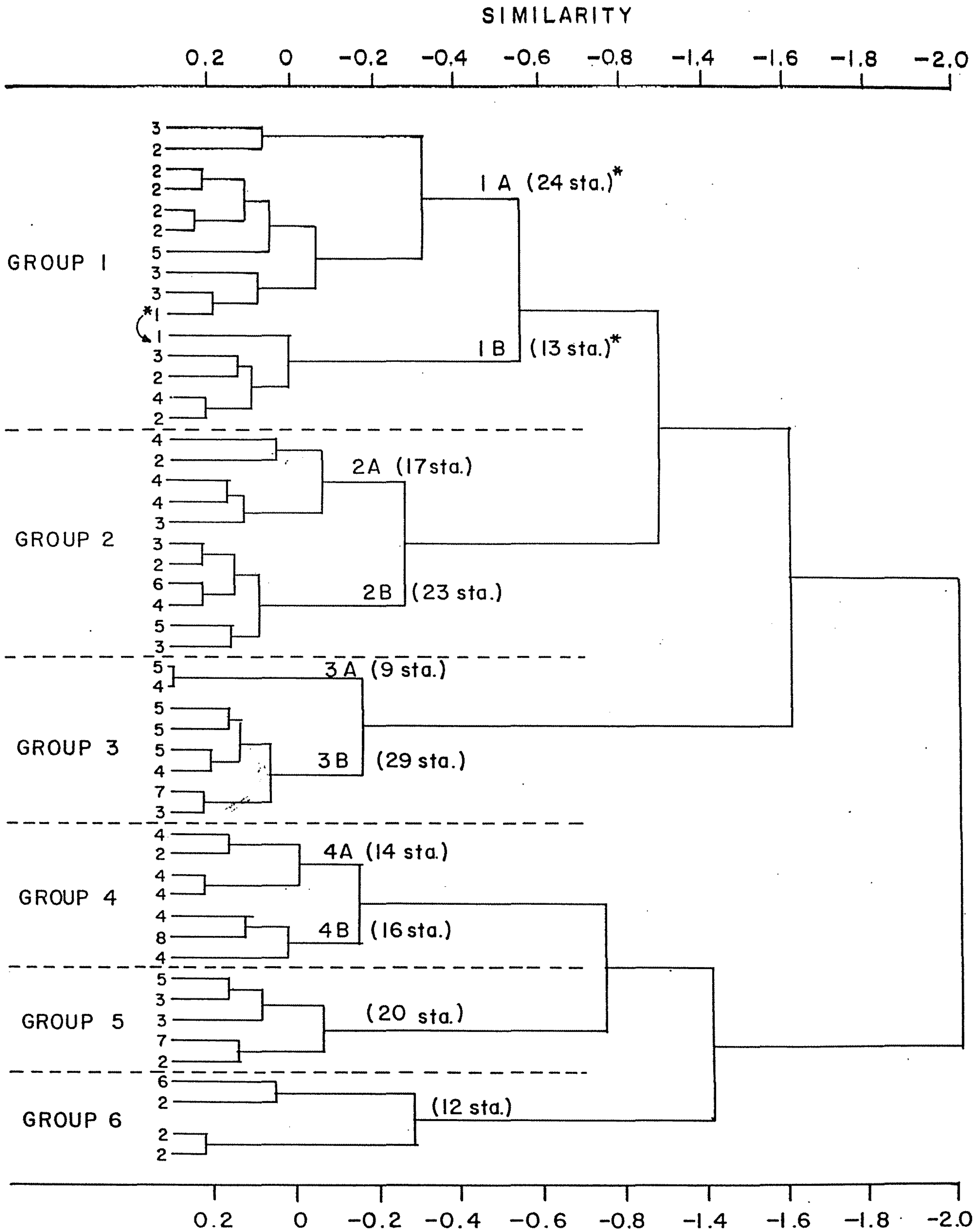
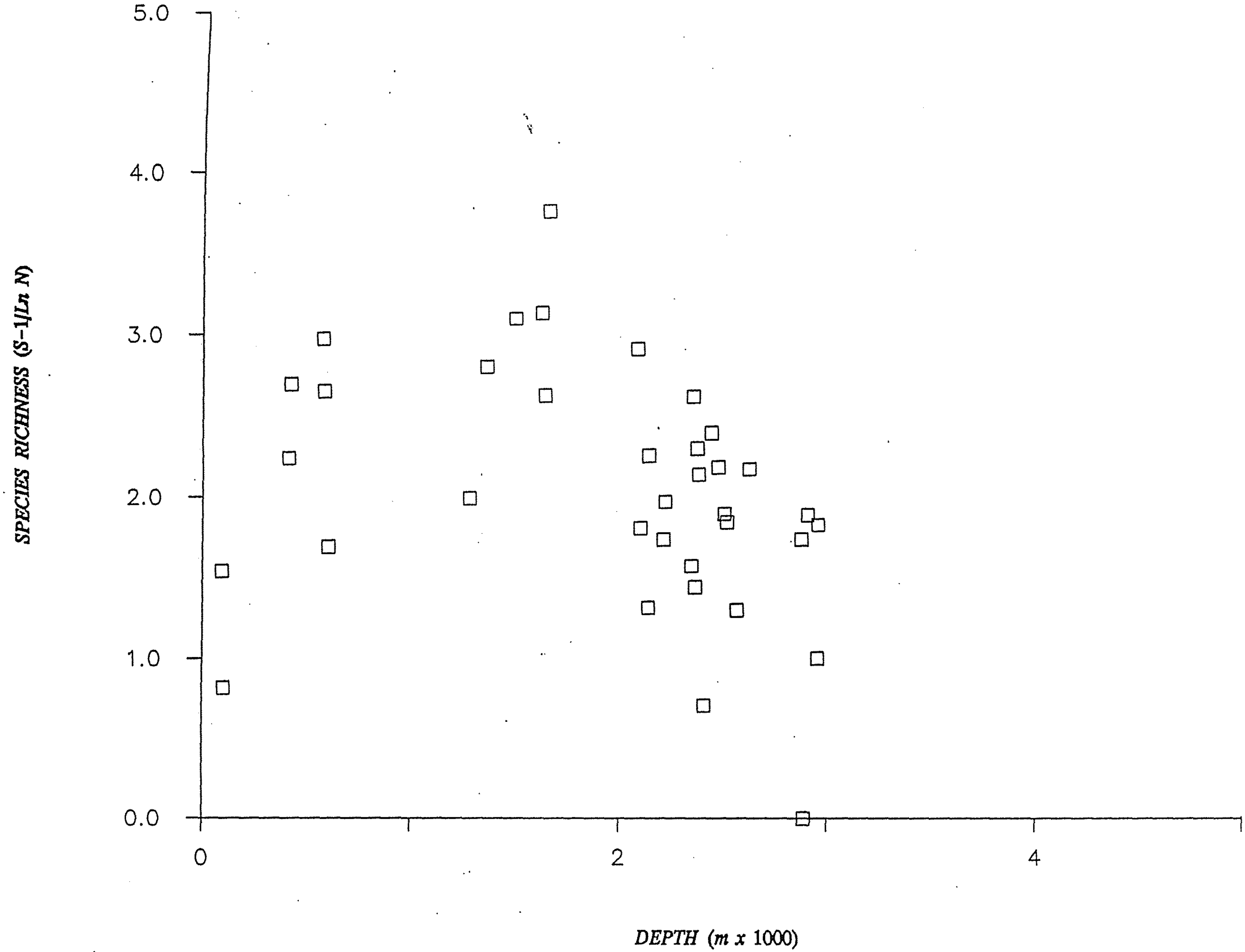
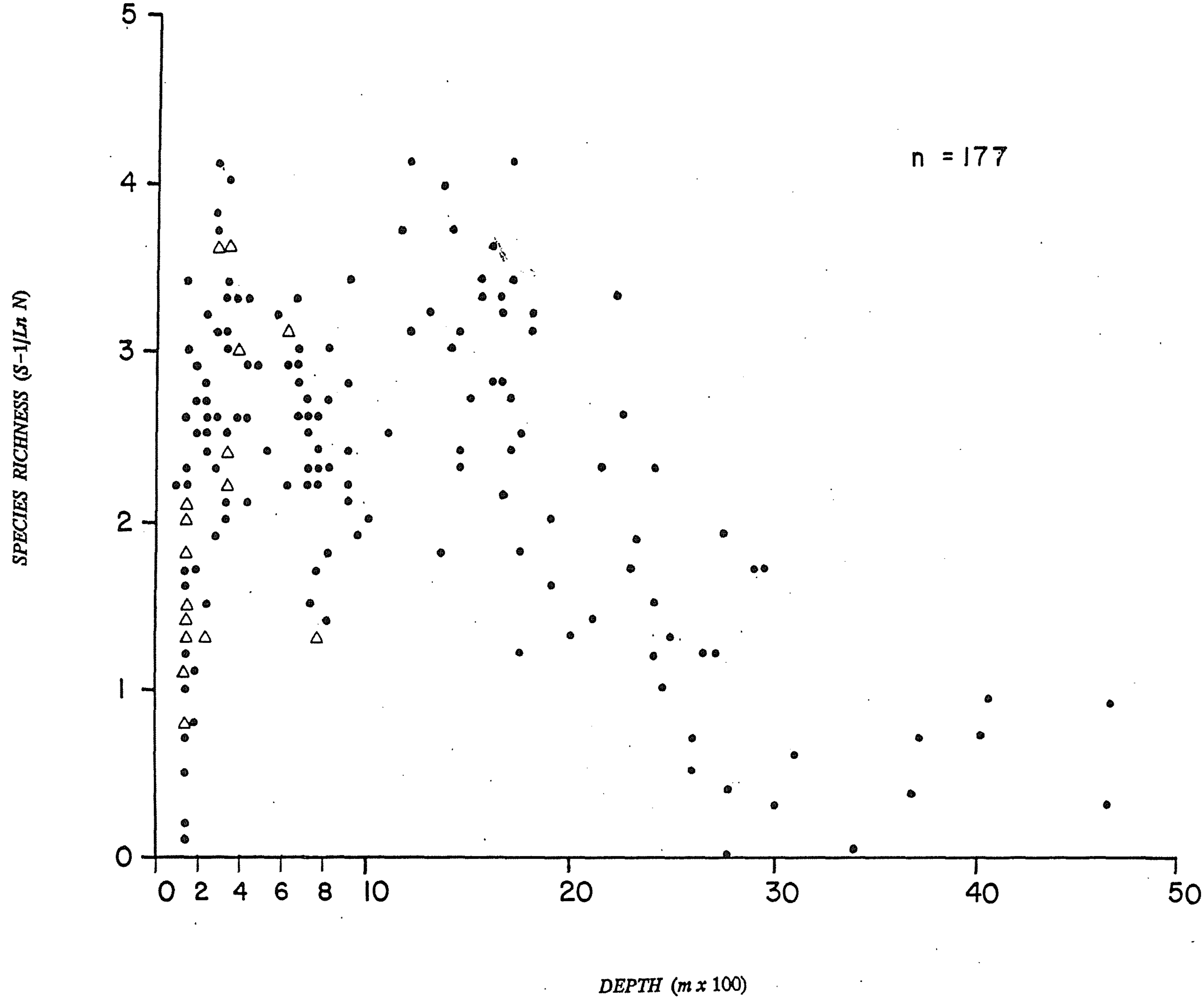

SIMILARITY
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.4
-1.6
-1.8
-2.0
GROUP 1
1 A (24 sta.)*
1 B (13 sta.)*
GROUP 2
2A (17sta.)
2B (23 sta.)
GROUP 3
3 A (9 sta.)
3 B (29 sta.)
GROUP 4
4A (14 sta.)
4B (16 sta.)
GROUP 5
(20 sta.)
GROUP 6
(12 sta.)

Figure 6. Bathymetric pattern of species richness with depth for recent data set.



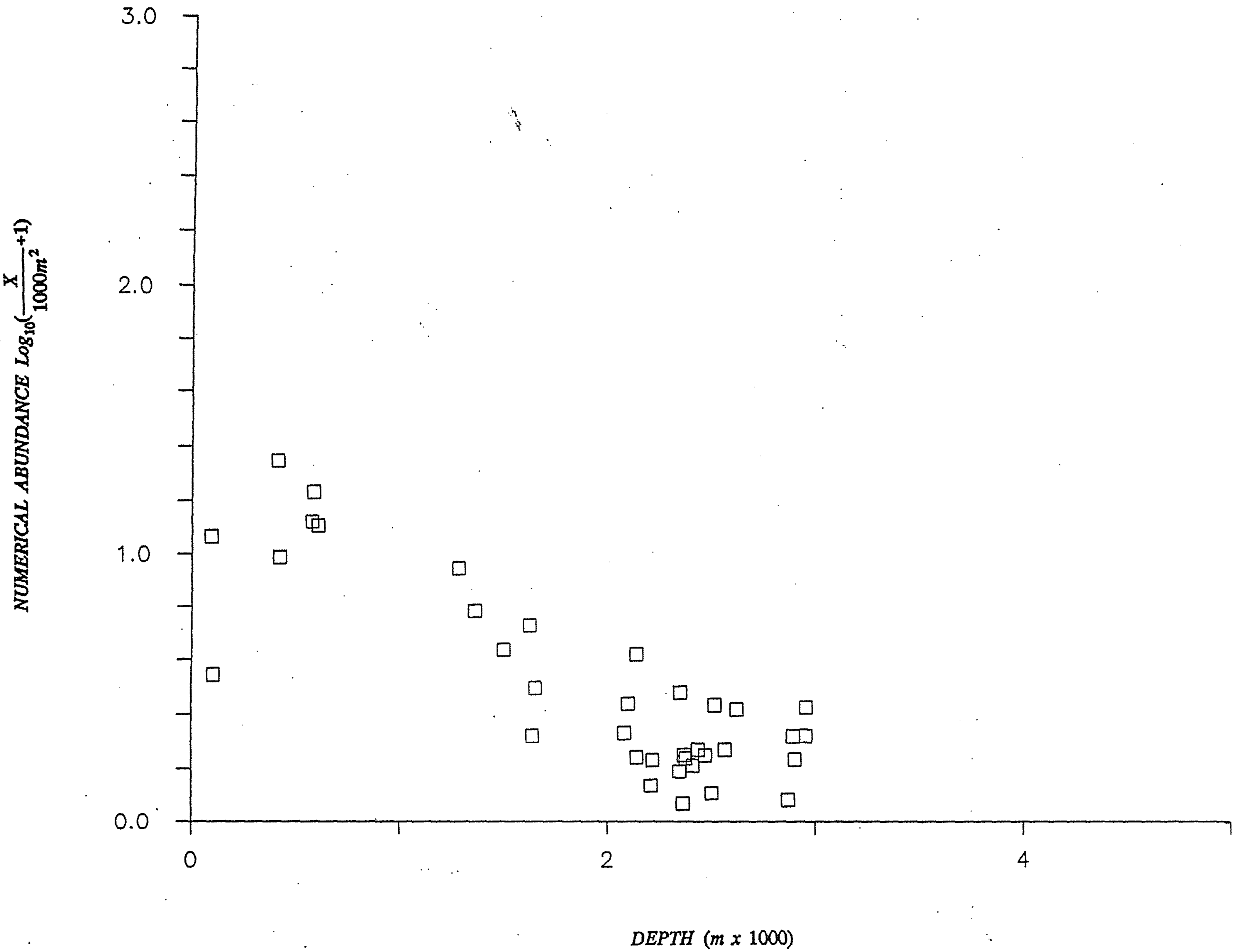
SPECIES RICHNESS (S-1/Ln N)
5.0
4.0
3.0
2.0
1.0
0.0
0
2
4
DEPTH (m x 1000)

Figure 7. Bathymetric pattern of species richness with depth for historical data set.



n = 177
SPECIES RICHNESS (S-1/Ln N)
DEPTH (m x 100)
0
1
2
3
4
5
0
2
4
6
8
10
20
30
40
50

Figure 8. Bathymetric pattern of numerical abundance with depth for recent data set.



3.0
2.0
1.0
0.0
0
2
4
NUMERICAL ABUNDANCE $Log_{10}(\frac{X}{1000m^2}+1)$
DEPTH (m x 1000)

Figure 9. Bathymetric pattern of numerical abundance with depth for historical data set.

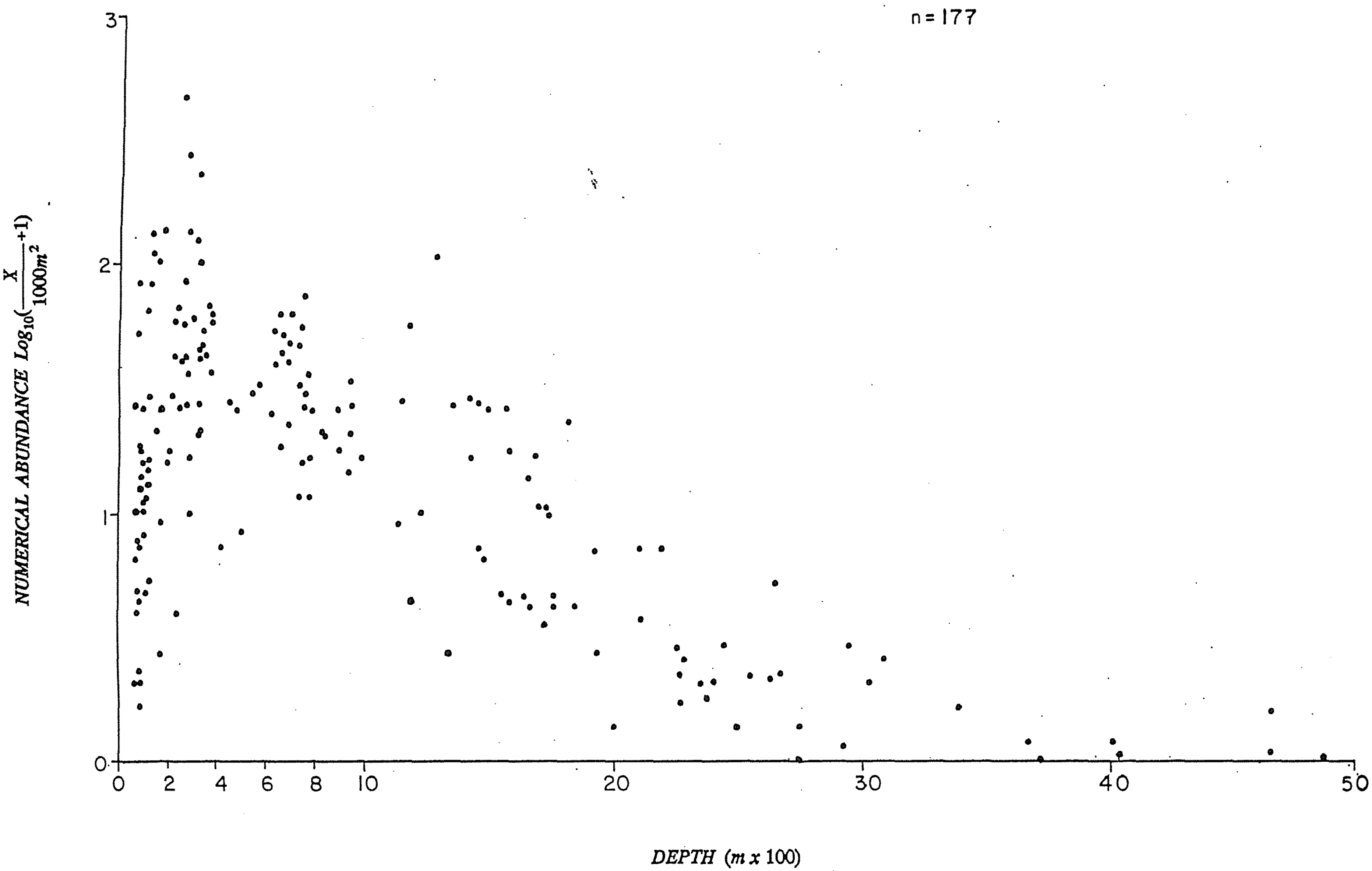
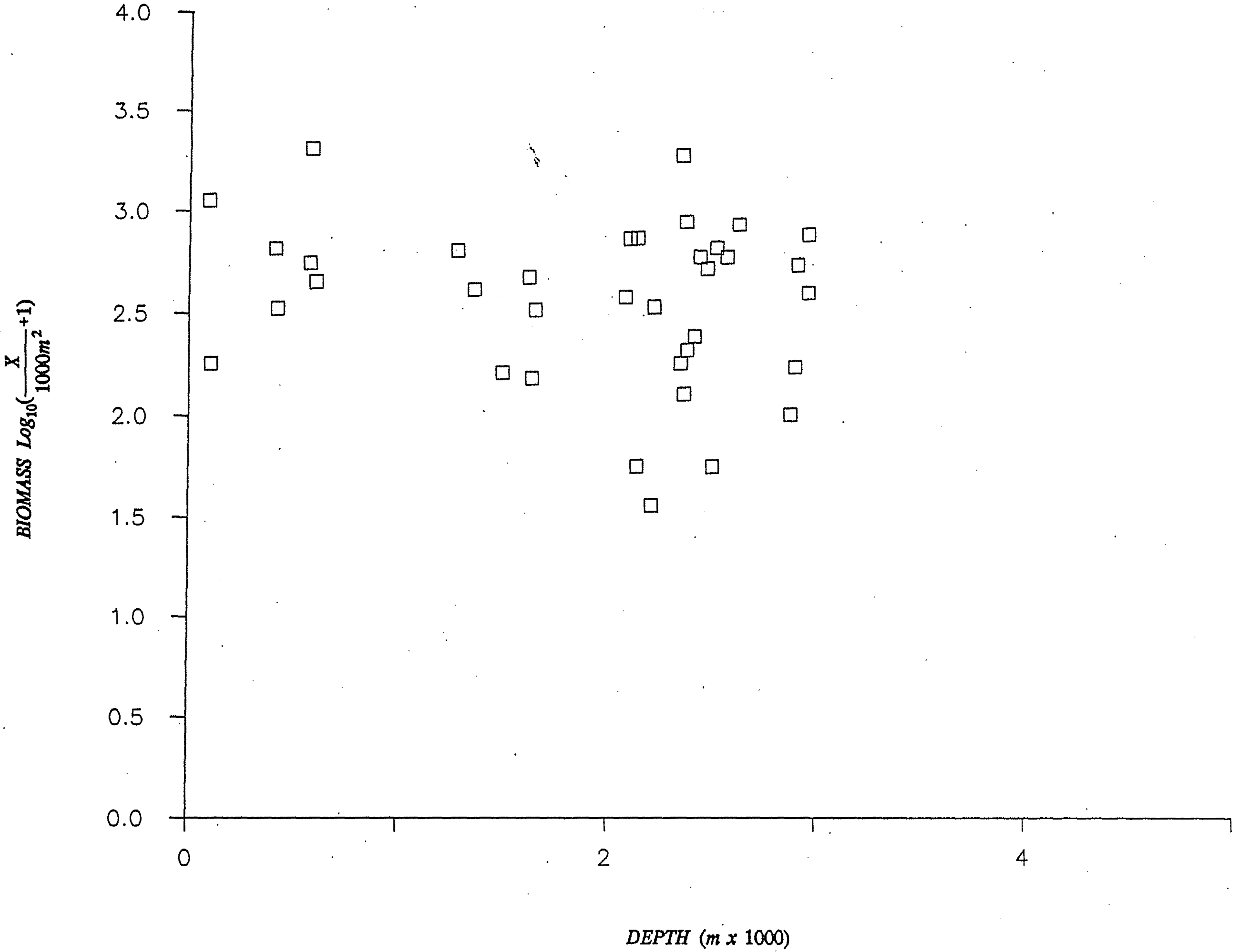
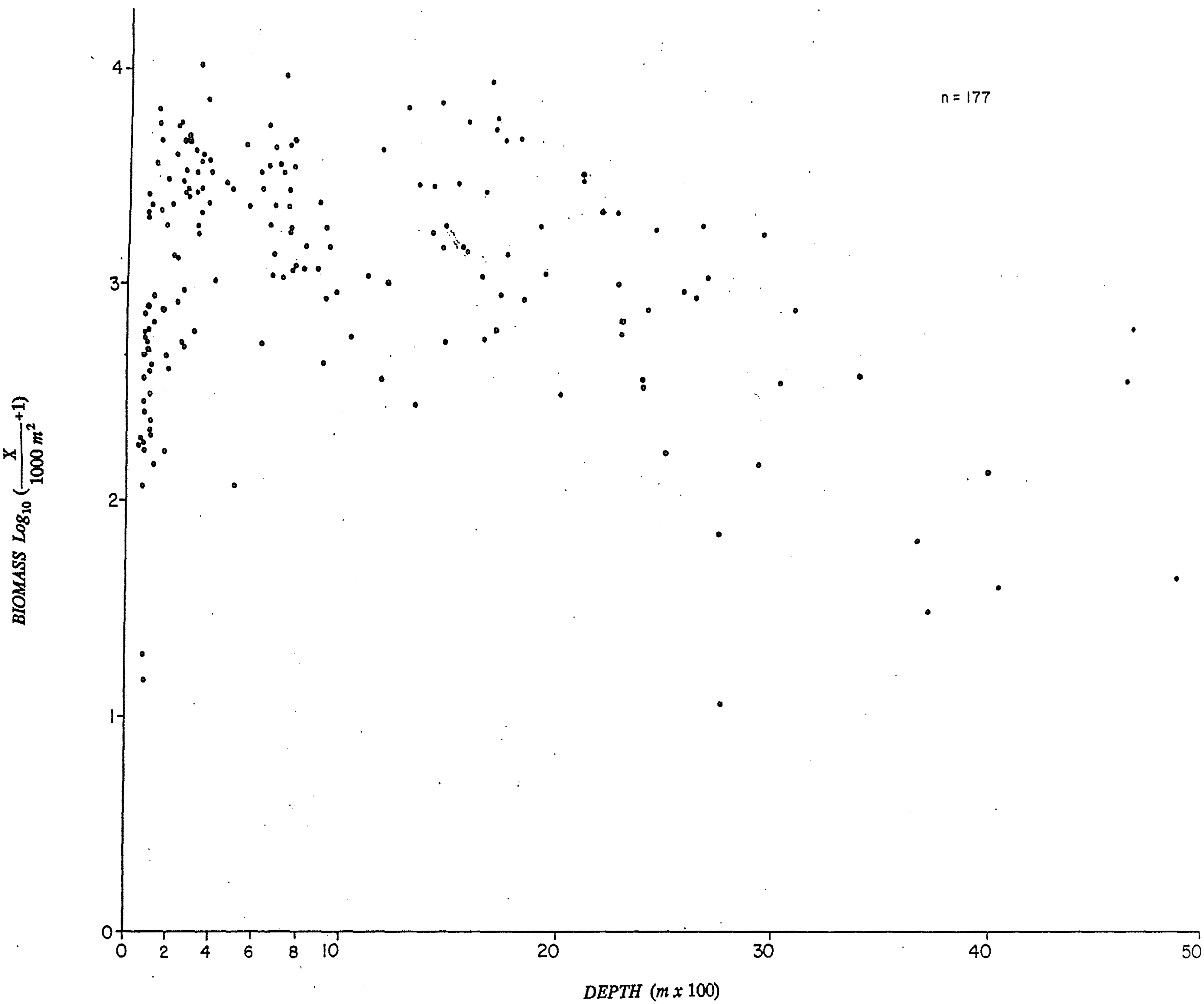

n = 177
3
2
1
0
0
2
4
6
8
10
20
30
40
50
NUMERICAL ABUNDANCE $Log_{10}(\frac{X}{1000m^2}+1)$
DEPTH (m x 100)

Figure 10. Bathymetric pattern of biomass with depth for recent data set.



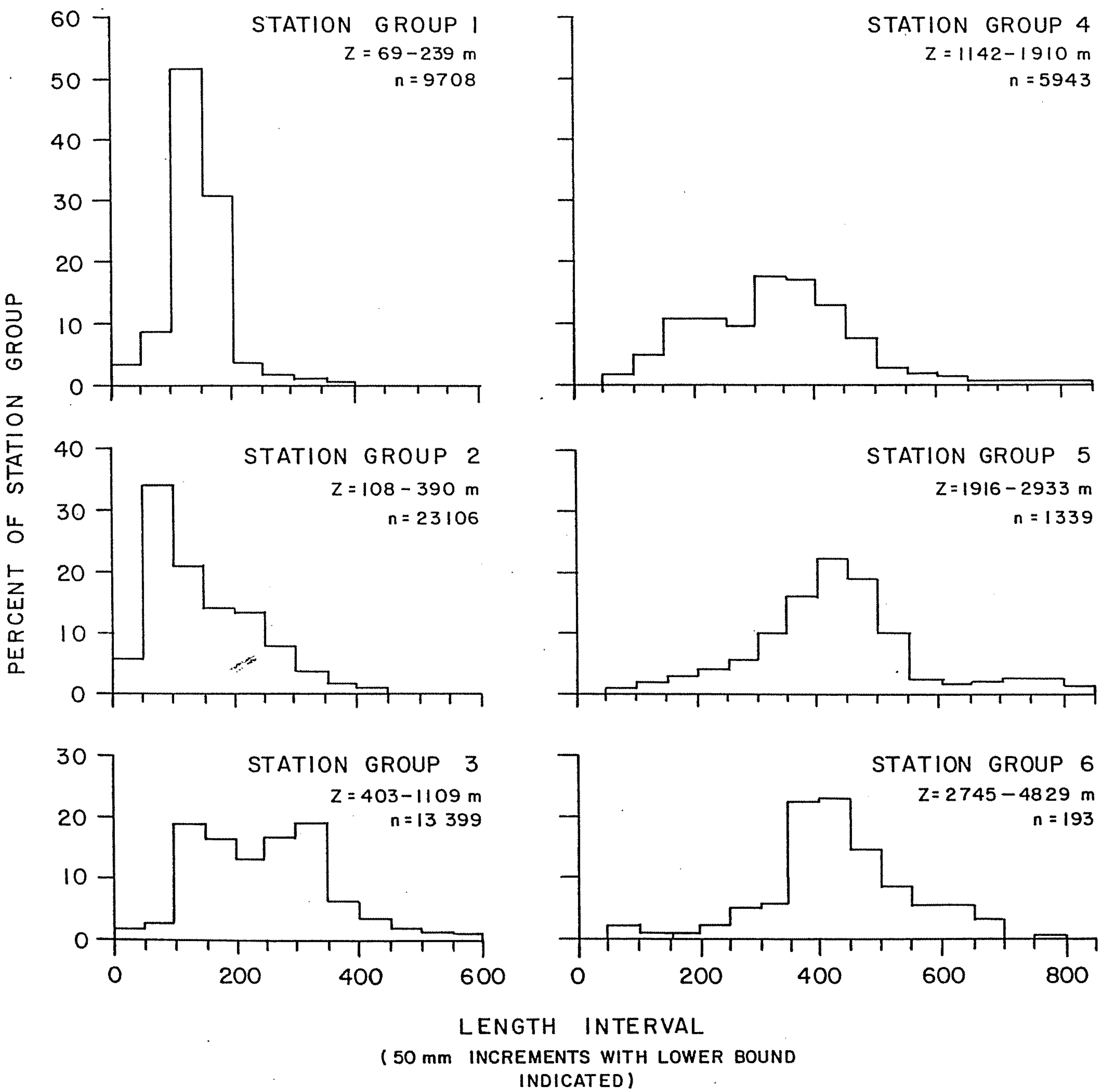
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
BIOMASS $Log_{10}(\frac{X}{1000m^2}+1)$
DEPTH (m x 1000)

Figure 11. Bathymetric pattern of biomass with depth for historical data set.



n = 177
BIOMASS $Log_{10}\left(\frac{X}{1000\ m^2}+1\right)$
0
1
2
3
4
0 2 4 6 8 10 20 30 40 50
DEPTH (m x 100)

Figure 12. Length-frequency distributions of fishes captured at six bathymetric station groups (historical data set).


STATION GROUP 1
Z = 69-239 m
n = 9708
STATION GROUP 4
Z = 1142-1910 m
n = 5943
STATION GROUP 2
Z = 108-390 m
n = 23106
STATION GROUP 5
Z = 1916-2933 m
n = 1339
STATION GROUP 3
Z = 403-1109 m
n = 13 399
STATION GROUP 6
Z = 2745-4829 m
n = 193
PERCENT OF STATION GROUP
0
10
20
30
40
50
60
0
200
400
600
800
LENGTH INTERVAL
(50 mm INCREMENTS WITH LOWER BOUND INDICATED)

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Appendices

Appendix 1. DE 90-09 Raw data for successful trawls- benthic species.

SPECIES	STA / Z(m)	1 / 93	10 / 105	11 / 575	A4 / 1279	H13 / 1563	H11 / 1559	H6 / 2079	H2 / 2097	H10 / 2208	H4 / 2216	9 / 2363	31 / 2469	HG / 2500	H12 / 2563	15 / 2869	25 / 2890	26 / 2899	SPECIES TOTALS #	Biomass
Hydrolagus	#							1											1	
affinis	gms							62												62
Hariotta														1					1	
raleighana														380						380
Etmopterus				1															1	
gracilispinis				33																33
Centroscyllium						1													1	
fabricii						1000														1000
Centroscymnus					1														1	
coelolepis					781															781
Scyliorhinus		6																	6	
retifer		990																		990
Apristurus						1													1	
profundorum						69														69
Raja										2									2	
bigelowi										547										547
Raja			1																1	
garmani			385																	385
Raja													3						3	
jenseni													5340							5340
Aldrovandia					3	1	2												6	
affinis					212	52.3	17.6													281.9
Aldrovandia							5	1											6	
oleosa							45.7	49												94.7
Aldrovandia						5	2		1										8	
phalacra						172.2	61.2		10											243.4
Halosauropsis						1		16	7	11	1	1	9	3	3	2			54	
macrochir						420		3630	2100	4000	187	285	3500	800	1300	1150				17372
Polyacanthonotus							1												1	
merretti							32													32
Ilyophis								1					2	2	1				6	
brunneus								132					60	46.6	24					263
Synaphobranchus																1		1	2	
bathybius																31		220		251

Appendix 1. (cont.)

SPECIES	STA Z(m)	1 93	10 105	11 575	A4 1279	H13 1563	H11 1559	H6 2079	H2 2097	H10 2208	H4 2216	9 2363	31 2469	HG 2500	H12 2563	15 2869	25 2890	26 2899	SPECIES TOTALS #	SPECIES TOTALS Biomass
Synaphobranchus				64	39	31	8	3	2	26									173	
kaupi				1093	2600	2050	183	117	221	2559										8823
Simenchelys					2	2													4	
parasitica					250	245														495
Nettastoma							1												1	
melanura							99													99
Alepocephalus						2	9	1	2				1						15	
agassizii						370	1112	520	2150				1000							5152
Alepocephalus									2										2	
spp.									90											90
Narcetes										3									3	
stomias										3400										3400
Bathypterois									1	1									2	
grallator									73	83										156
Bathypterois										1									1	
phenax										3										3
Bathypterois					1														1	
quadrifilis					19															19
Bathysaurus							1	2			1								4	
ferox							260	88			879									1227
Bathysaurus																		2	2	
mollis																		4537		4537
Antimora					4			13	14	33	19	4	9	1	20				117	
rostrata					238			13750	15000	33250	13300	5500	11000	1200	23350					116588
Brosmiculus				2															2	
imberbis				143																143
Enchelyopus				1															1	
cimbrius				12																12
Gaidropsarus								1											1	
ensis								271												271
Unid. Morid						1													1	
						4														4
Phycis				72															34	
chesteri				5090																5090
Urophycis		25																	25	
chuss		2700																		2700

Appendix 1. (cont.)

	STA	1	10	11	A4	H13	H11	H6	H2	H10	H4	9	31	HG	H12	15	25	26	SPECIES TOTALS	
SPECIES	Z(m)	93	105	575	1279	1563	1559	2079	2097	2208	2216	2363	2469	2500	2563	2869	2890	2899	#	Biomass
Urophycis		79	28																107	
regia		11500	1900																	13400
Urophycis				2															2	
tenuis				1100																1100
Merluccius				4															4	
albidus				600																600
Merluccius		14																	14	
bilinearis		2458																		2458
Coryphaenoides				9				2		3	4		10	2	18	5	56	16	125	
armatus				800				900		600	1700		5000	175.5	7220	3400	8816	7500		36111.5
Coryphaenoides							12	16	19	48	7	2	1	5	4			2	116	
carapinus							104	800	238	2181	207	37	138	146.3	316			75		4242.3
Coryphaenoides					7														7	
rupestris					857															857
Nezumia				35	26														61	
bairdi				732	1343															2075
Ventrifossa				1															1	
occidentalis				34																34
Barathrites							2	1											3	
parri							21	7												28
Barathrodemus																		1	1	
manatinus																		5500		5500
Dicrolene					7	25	1												33	
intronigra					307	1500	77													1884
Diplacanthopoma				7															7	
spp. ?				162																162
Lepophidium		29																	29	
profundorum		1000																		1000
Parabassogigas										8									8	
crassus										352										352
Porogadus								4		13	1	1	3		1	1		1	25	
miles								32		156	82	46	140		71	94		89		710
Unid. Ophidioid																1			1	
																25				25
Lophius		1																	1	
americanus		329																		329

Appendix 1. (cont.)

	STA	1	10	11	A4	H13	H11	H6	H2	H10	H4	9	31	HG	H12	15	25	26	SPECIES TOTALS	
SPECIES	Z(m)	93	105	575	1279	1563	1559	2079	2097	2208	2216	2363	2469	2500	2563	2869	2890	2899	#	Biomass
Lophiiforme						1													1	
						5														5
Bathychaunax											1								1	
roseus											48									48
Dibranchus				2															2	
atlanticus				59																59
Acanthochaenus										2			1						3	
lutkenii										42			20							62
Helicolenus				22															22	
dactylopterus				1806																1806
Peristedion				1															1	
spp.				2																2
Cottunculus					1														1	
thompsoni					800															800
Paraliparis				1															1	
spp.				9																9
Lycenchelys						1	2											1	4	
paxillus						8	35											30		73
Lycenchelys				3															3	
verrilli				11																11
Lycodes							2			2	1								5	
atlanticus							278			52	338									668
Melanostigma				2															2	
spp.				20																20
Peprilus		4	6			1													11	
triacanthus		2	174			4														180
Citharichthys		22																	22	
arctifrons		132																		132
Paralichthys		1	4																5	
oblongus		104	306																	410
Glyptocephalus				76															76	
cynoglossus				2183																2183
STATION TOTALS																				
# SPECIES		9	4	18	10	13	13	13	8	13	8	4	9	6	6	5	1	7	(69 spp.)	
# INDIVIDUALS		181	39	305	91	73	48	62	48	153	35	8	39	14	47	10	56	24	1233	
BIOMASS (gms)		19215	2765	13889	7407	5899.5	2325.5	20358	19882	47225	16741	5868	26198	2748.4	32281	4700	8816	17951		254269.4

Appendix 2. DE 91-09 Raw data for successful trawls- benthic species.

	STA	11	5	29	18	H13	H11	6	H10	H2	H4	24	4	H6	20
SPECIES	Z(m)	413	423	581	605	1621	1637	1652	2138	2208	2344	2346	2368	2376	2410
Myxine	#	2													
glutinosa	gms	90													
Hydrolagus							1						1		
affinis							1750						15000		
Hariotta								1							
raleighana								1275							
Raja						1									
bathyphila						400									
Raja		1													
garmani		135													
Raja			2												
jenseni			166.5												
Raja		1		1											
radiata		20		107											
Raja														1	
spinicauda														2850	
Aldrovandia								1							
affinis								81							
Aldrovandia						2		2							
phalacra						81		63							
Halosauropsis						1		3	3	2		6	5	4	2
macrochir						425		800	1000	800		2400	1600	1250	500
Polyacanthonotus															
challengeri															
Ilyophis						8		2							
brunneus						154		89							
Synaphobranchus		1		2	11										
affinis		7		16.5	174										
Synaphobranchus						1	1					1			
bathybius						275	143					60			
Synaphobranchus				48	29	68	17	19	2		1				
kaupi				989.3	945	4600	1700	2688	167		16				
Synaphobranchus				1											
spp.				2.2											

Appendix 2. (cont.)

	STA	11	5	29	18	H13	H11	6	H10	H2	H4	24	4	H6	20
SPECIES	Z(m)	413	423	581	605	1625	1637	1652	2138	2208	2344	2346	2368	2376	2410
Simenchelys						4						1			
parasitica						750						158			
Alepocephalus						3		5						2	
agassizii						500		600						1400	
Alepocephalus							1	3				1			
spp.							29.5	50				1000			
Bathytroctes															
squamosus															
Conocara													1		
murrayi													226		
Narcetes														1	
stomias														1000	
Chlorophthalmus			3												
agassizii			62												
Bathypterois													1		
phenax													6		
Bathysaurus						2	1	1				1		1	
ferox						2050	48.5	92				1900		124	
Bathysaurus															
mollis															
Notolepis															
rissoi															
Antimora						9		4			5	59	6	4	
rostrata						3300		1950			6500	77500	6300	3200	
Halargyreus								1							
johnsoni								319							
Laemonema						1	2			1	2		1		
spp.						4	6			4	8		3		
Enchelyopus		2	2	2	1										
cimbrius		17	27.5	28	1										
Gaidropsarus												1			
ensis												197			
Phycis		76	23	139	15										
chesteri		1885	600	19250	2550										
Urophycis			3	7											
tenuis			1250	6300											
Merluccius		7	4	9	1										
albidus		1550	1500	5500	550										

Appendix 2. (cont.)

SPECIES STA	11	5	29	18	H13	H11	6	H10	H2	H4	24	4	H6	20
Z(m)	413	423	581	605	1625	1637	1652	2138	2208	2344	2346	2368	2376	2410
<u>Caelorinchus</u>	2	1												
<u>carminatus</u>	142	42												
<u>Coryphaenoides</u>										5	20	2		5
<u>armatus</u>										1050	7300	40		4800
<u>Coryphaenoides</u>														
<u>brevibarbis</u>														
<u>Coryphaenoides</u>					10	5	7	12	5	9	2	4	26	10
<u>carapinus</u>					93	200	14.3	343	99	300	17	500	2000	1300
<u>Coryphaenoides</u>							2							
<u>hexti</u>							113.8							
<u>Coryphaenoides</u>														
<u>leptolepis</u>														
<u>Coryphaenoides</u>														
spp.														
<u>Nezumia</u>	119	57	124	46										
<u>bairdi</u>	323	135.5	1800	571										
<u>Barathrites</u>					1									
<u>parri</u>					33									
<u>Benthocometes</u>		1					1							
<u>robustus</u>		5					3.5							
<u>Dicrolene</u>					6	1	1							
<u>intronigra</u>					420	190	50							
<u>Parabassogigas</u>							1				2			
<u>crassus</u>							7.5				84			
<u>Penopus</u>											1		1	
<u>macdonaldi</u>											9		6.6	
<u>Penopus</u>														
spp.														
<u>Porogadus</u>						1		2	1	2			2	
<u>miles</u>						14		57	52	24			48.4	
Unid. Ophidioid			1											
			4											
<u>Lophius</u>	2	2	5											
<u>americanus</u>	56	44	17000											
Lophiiforme														

Appendix 2. (cont.)

SPECIES	STA Z(m)	11 413	5 423	29 581	18 605	H13 1625	H11 1637	6 1652	H10 2138	H2 2208	H4 2344	24 2346	4 2368	H6 2376	20 2410
<u>Dibranchus</u>		11		2	1										
<u>atlanticus</u>		282		44	16										
<u>Cryptosarus</u>															
<u>cousei</u>															
<u>Linophryne</u>															
<u>algibarbata</u>															
<u>Anoplogaster</u>															
spp.															
<u>Acanthochaenus</u>										1					
<u>lutkenii</u>										9					
<u>Helicolenus</u>		15	2	4	4										
<u>dactylopterus</u>		1300	132	550	450										
<u>Careproctus</u>				1											
<u>ranula</u>				11											
<u>Synagrops</u>			1												
spp.			12.5												
<u>Apogon</u>									2			1			
spp.									9			6			
<u>Lycenchelys</u>		2	8	52	36										
<u>verrilli</u>		9	40.5	214	237										
<u>Lycodes</u>						2	1					3			
<u>atlanticus</u>						55	182					650			
<u>Melanostigma</u>						1									
<u>atlanticum</u>						14									
<u>Reinhardtius</u>				1											
<u>hippoglossoides</u>				335											
<u>Glyptocephalus</u>		88	16	22	59										
<u>cynoglossus</u>		4300	754	1233	2300										
STATION TOTALS															
# SPECIES		14	14	17	10	16	10	16	5	5	6	13	8	9	3
# INDIVIDUALS		329	125	421	203	120	31	54	21	10	24	99	21	42	17
BIOMASS (gms)		10116	4771.5	53384	7794	13154	4263	8250.1	1576	964	7898	91281	23675	11879	6600

Appendix 2. (cont.)

	STA	30	H12	HG	26	25	SPECIES TOTALS	
SPECIES	Z(m)	2435	2513	2619	2950	2952	# of Individuals	Biomass (gms)
<u>Myxine</u>	#						2	
<u>glutinosa</u>	gms							90
<u>Hydrolagus</u>							2	
<u>affinis</u>								16750
<u>Hariotta</u>							1	
<u>raleighana</u>								1275
<u>Raja</u>							1	
<u>bathyphila</u>								400
<u>Raja</u>							1	
<u>garmani</u>								135
<u>Raja</u>							2	
<u>jenseni</u>								166.5
<u>Raja</u>							2	
<u>radiata</u>								127
<u>Raja</u>							1	
<u>spinicauda</u>								2850
<u>Aldrovandia</u>							1	
<u>affinis</u>								81
<u>Aldrovandia</u>							4	
<u>phalacra</u>								144
<u>Halosauropsis</u>		1	1	4			32	
<u>macrochir</u>		235	300	1300				10610
<u>Polyacanthonotus</u>				1			1	
<u>challengeri</u>				282				282
<u>Ilyophis</u>		1					11	
<u>brunneus</u>		35						278
<u>Synaphobranchus</u>							14	
<u>affinis</u>								197.5
<u>Synaphobranchus</u>						2	5	
<u>bathybius</u>						850		1328
<u>Synaphobranchus</u>							184	
<u>kaupi</u>								11105.3
<u>Synaphobranchus</u>							1	
spp.								2.2

Appendix 2. (cont.)

SPECIES	STA Z(m)	30 2435	H12 2513	HG 2619	26 2950	25 2952	SPECIES TOTALS # of Individuals	Biomass (gms)
Simenchelys							5	
parasitica								908
Alepocephalus							10	
agassizii								2500
Alepocephalus		1	1			1	8	
spp.		850	13			23		1965.5
Bathytroctes				1			1	
squamosus				16				16
Conocara				1			2	
murrayi				242				468
Narcetes							1	
stomias								1000
Chlorophthalmus							3	
agassizii								62
Bathypterois							1	
phenax								6
Bathysaurus		1					7	
ferox		600						4814.5
Notolepis				1			1	
rissoi				95				95
Bathysaurus						1	1	
mollis						6750		6750
Antimora		19	10	16			132	
rostrata		21000	12000	22000				153750
Halargyreus							1	
johnsoni								319
Laemonema			1	1			9	
spp.			4.5	5				34.5
Enchelyopus							7	
cimbrius								73.5
Gaidropsarus							1	
ensis								197
Phycis							253	
chesteri								24285
Urophycis							10	
tenuis								7550
Merluccius							21	
albidus								9100

Appendix 2. (cont.)

SPECIES	STA Z(m)	30 2435	H12 2513	HG 2619	26 2950	25 2952	SPECIES TOTALS # of Individuals	Biomass (gms)
Caelorinchus							3	
carminatus								184
Coryphaenoides		15	18	57	46	61	229	
armatus		6500	7613	26656	19000	26400		99359
Coryphaenoides			1				1	
brevibarbis			58.3					58.3
Coryphaenoides		2	43	15	4	7	161	
carapinus		53	9268	1500	113	1500		17300.3
Coryphaenoides							2	
hexti								113.8
Coryphaenoides						1	1	
leptolepis						600		600
Coryphaenoides			1				1	
spp.			132					132
Nezumia							346	
bairdi								2829.5
Barathrites				2			3	
parri				94				127
Benthocometes							2	
robustus								8.5
Dicrolene							8	
intronigra								660
Parabassogigas							3	
crassus								91.5
Penopus		1					3	
macdonaldi		79						94.6
Penopus						1	1	
spp.						42		42
Porogadus		1			2	5	16	
miles		59			191	365		810.4
Unid. Ophidioid							1	
								4
Lophius							9	
americanus								17100
Lophiiforme					1		1	
					5			5

Appendix 3. DE 90-09 Raw data for successful trawls- pelagic species.

	STA	1	10	11	A4	H13	H11	H6	H2	H10	H4	9	31	HG	H12	15	25	26	SPECIES TOTALS	
SPECIES	Z(m)	93	105	575	1279	1563	1559	2079	2097	2208	2216	2363	2469	2500	2563	2869	2890	2899	#	Biomass
Derichthys	#									1							1		2	
serpentinus	gms									21							20			41
Nessorhamphus							1			1	1								3	
ingolfianus							3			7	8									18
Serrivomer									1	1	2	20	1				2	1	28	
beani									72	2	26	155	25				52	63		395
Nemichthys				1	1	2	3	1	1				2		1				12	
scolopaceous				19	24	24	83	12	5				17		20					204
Eurypharynx													1						1	
pelecanoides													15							15
Eurypharynx						1													1	
spp.						32														32
Cyclothone						1													1	
spp.						2														2
Gonostoma						2			9	2			2		2	1	2	1	21	
bathyphilum						66			138	52			72		40	14	20	40		442
Sternoptichidae				3	1		1		2	1									8	
				5	8		4		9	15										41
Chauliodus									3										3	
sloani									117											117
Stomias				3															3	
boa ferox				34																34
Myctophidae				16	7	32	5			2				2				1	65	
				31	15	130	30			4				4				7		221
Melamphaidae						3			1	2			2				1		9	
						106			28	35			29				22			220
Chiasmodon													1						1	
niger													18							18
Kali									1										1	
spp.									43											43
STATION TOTALS																				
# SPECIES				4	3	6	4	1	7	7	2	1	6	1	2	1	4	3	(15+)	
# INDIVIDUALS				23	9	41	10	1	18	10	3	20	9	2	3	1	6	3	159	
BIOMASS (gms)				89	47	360	120	12	412	136	34	155	176	4	60	14	114	110		1843

Appendix 2. (cont.)

SPECIES	STA Z(m)	30 2435	H12 2513	HG 2619	26 2950	25 2952	SPECIES TOTALS # of Individuals	Biomass (gms)
Dibranchus							14	
atlanticus								342
Cryptosarus		1					1	
cousei		66						66
Linophryne						1	1	
algibarbata						32		32
Anoplogaster					1		1	
spp.					96			96
Acanthochaenus							1	
lutkenii								9
Helicolenus							25	
dactylopterus								2432
Careproctus							1	
ranula								11
Synagrops							1	
spp.								12.5
Apogon							3	
spp.								15
Lycenchelys							98	
verrilli								500.5
Lycodes							6	
atlanticus								887
Melanostigma							1	
atlanticum								14
Reinhardtius							1	
hippoglossoides								335
Glyptocephalus							185	
cynoglossus								8587
Unid. Fish			1	1			2	
			27	6				33
STATION TOTALS								
# SPECIES		10	9	11	5	9	(69 spp.)	
# INDIVIDUALS		43	77	100	54	80	1870	
BIOMASS (gms)		29477	29415.8	52196	19405	36562		412607.4

Appendix 4. DE 91-09 Raw data for successful trawls- pelagic species.

	STA	11	5	29	18	H13	H11	6	H10	H2	H4	24	4	H6	20
SPECIES	Z(m)	413	423	581	605	1621	1637	1652	2138	2208	2344	2346	2368	2376	2410
Derichthys	#						1		1		1		2		
serpentinus	gms						12		8		9.5		10		
Nessorhamphus					1		1						1		1
ingolfianus					16		27						5.5		10
Serrivomer				1		1	3	2	1	5	4		6	2	
beani				7		6	50	53	20	123	50		102	36	
Nemichthys		1		8	8	2	3		1	3	2	1	6		4
scolopaceus		5.5		80	61	37	21		15	12	19	39	61		79
Eurypharynx							1		1				1		2
pelecanoides							16		15				7		71
Bathylagus						2									1
compsus						132									17
Cyclothone						3	4				6	1	1		3
spp.						3.5	4				6	2	1		3
Gonostoma						4	2		10	4	6	4	4	1	4
bathyphilum						29	18		122	59	89.5	49	75	19	71
Gonostoma				3			1			3			1		
elongatum				84			24			42			40		
Vinceguerria									1						
spp.									1						
Sternoptichidae		5				1	2		3	4		1	1	1	1
		5				9	1		8	22		1	5	4	7
Polyipnus					1						1				
spp.					3						1				
Trigonolampa						1									
miriceps						144.7									
Malacosteus							1							1	
niger							4							16	
Photostomias															
guernei															
Chauliodus					1	1	1	1	1		2	2	2	2	
sloani					43	29	59	24	24		19	78	71	50.6	
Stomias				5		1	2			3			4	1	
boa ferox				79		6	54			60			69	35	

Appendix 4. (cont.)

SPECIES	STA Z(m)	30 2435	H12 2513	HG 2619	26 2950	25 2952	SPECIES TOTALS # of Individuals	Biomass (gms)
Derichthys	#		1		1		7	
serpentinus	gms		9		59			107.5
Nessorhamphus			1				5	
ingolfianus			10					68.5
Serrivomer			2		1	1	29	
beani			200		15	20		685
Nemichthys		9		1	4		53	
scolopaceus		30		8	83			550.5
Eurypharynx			2	1	1	1	10	
pelecanoides			40	15	37	89		290
Bathylagus							3	
compsus								149
Cyclothone							18	
spp.								19.5
Gonostoma		3	3	1	3	4	53	
bathyphilum		50	71	7	44	39		742.5
Gonostoma				2			10	
elongatum				25				215
Vinceguerria							1	
spp.								1
Sternoptichidae		1	1		1	4	26	
		26	4.5		2.5	10		105
Polyipnus							2	
spp.								4
Trigonolampa							1	
miriceps								144.7
Malacosteus							2	
niger								20
Photostomias				1	1		2	
guernei				24.2	9			33.2
Chauliodus			2	1			16	
sloani			50	57				504.6
Stomias			1	2	3	1	23	
boa ferox			7	49	11	1.8		371.8

Appendix 4. (cont.)

SPECIES	STA Z(m)	11 413	5 423	29 581	18 605	H13 1621	H11 1637	6 1652	H10 2138	H2 2208	H4 2344	24 2346	4 2368	H6 2376	20 2410
Myctophidae		12		20	35	18	25	1	27	34	29	1	12	1	5
		19.5		33	65	43	56.5	4	47	44	94	1	27	14	16
Melamphaidae						4	4	2	3	9	9	3	2	2	1
						64	53	38	54	132	130	66	46	68	44
<u>Chiasmodon niger</u>															
STATION TOTALS															
# SPECIES		3		5	5	11	14	4	10	8	9	7	13	8	9
# INDIVIDUALS		18		37	46	38	51	6	49	65	60	13	43	11	22
BIOMASS (gms)		30		283	188	503.2	399.5	119	314	494	418	236	519.5	242.6	318

Appendix 4. (cont.)

SPECIES	STA Z(m)	30 2435	H12 2513	HG 2619	26 2950	25 2952	SPECIES TOTALS # of Individuals	Biomass (gms)
Myctophidae		2	24	15	4	1	266	
		30	62.5	54	38	2		650.5
Melamphaidae		5	10	6	4		64	
		77	189	166	16			1143
<u>Chiasmodon</u>				1			1	
<u>niger</u>				14				14
STATION TOTALS								
# SPECIES		5	10	10	10	6	(20+ spp.)	
# INDIVIDUALS		20	47	31	23	12	592	
BIOMASS (gms)		213	643	419.2	314.5	161.8		5816.3